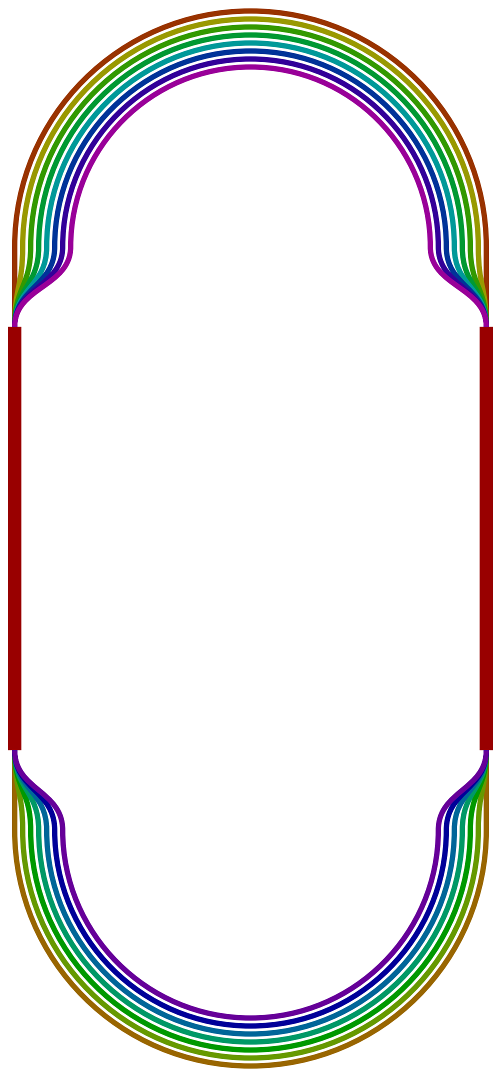
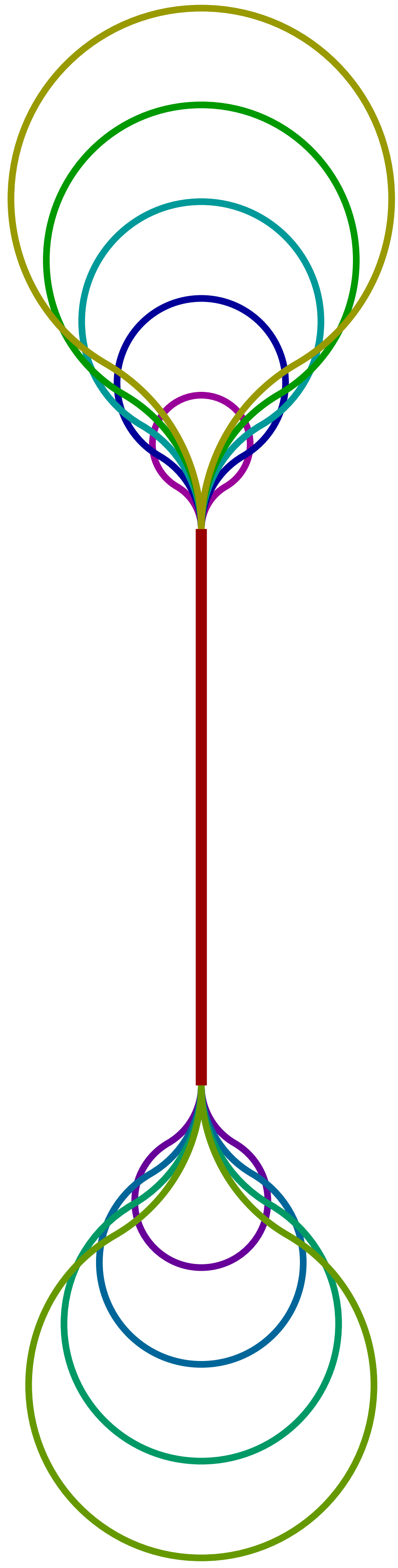
Idea Behind the Dogbone

- Only one linac per turn instead of two, but pass through twice
  - Half the linac for a given number of turns, or
  - Combine two linacs into one long linac
    - Low energy turn-arounds minimum length
    - $420°$ per pass
    - Compare to $360°$ arc per pass, but length from high energy
    - Easier switchyard!!!
  - Optimum some compromise between these



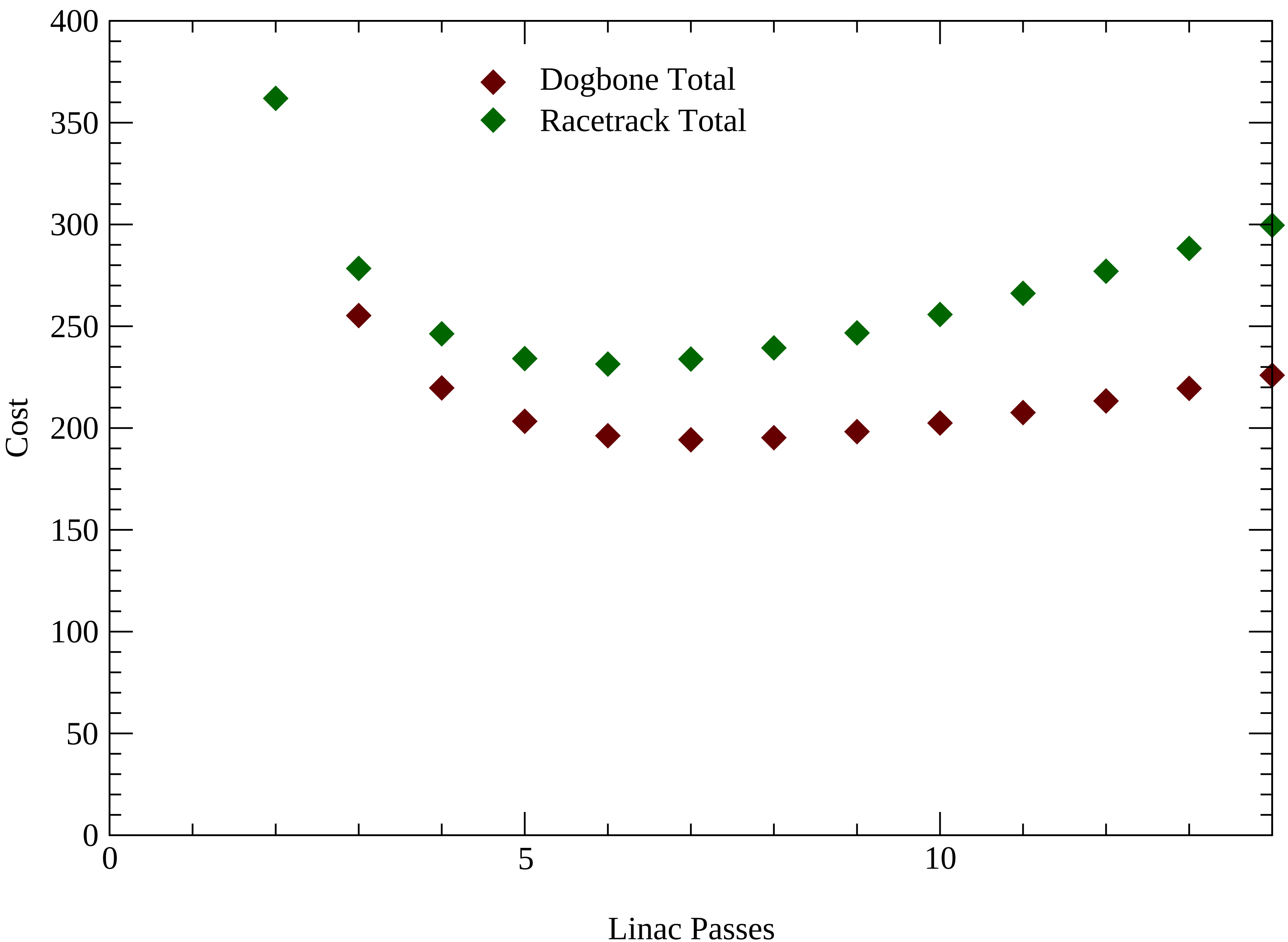


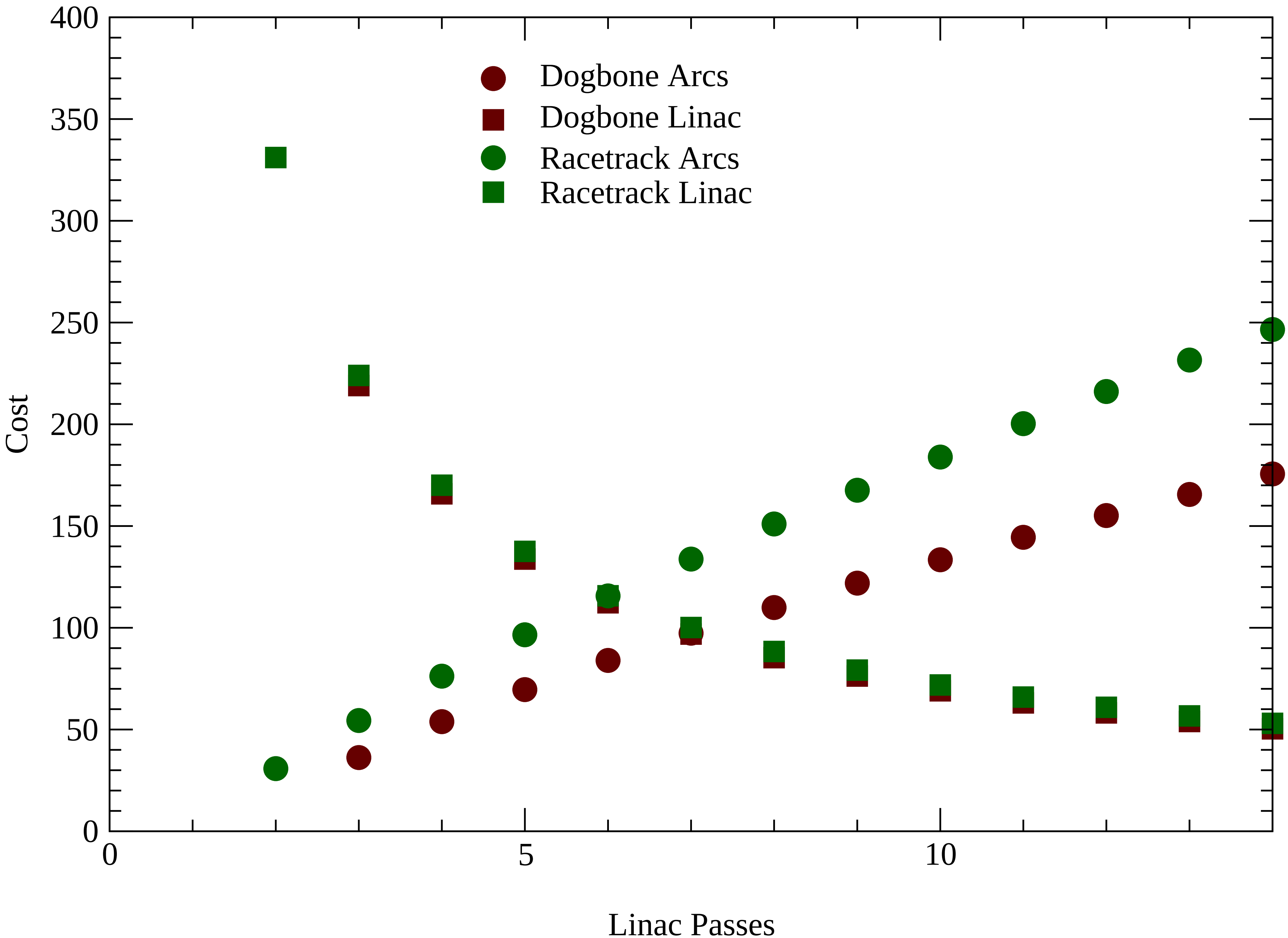
Cost Optimization

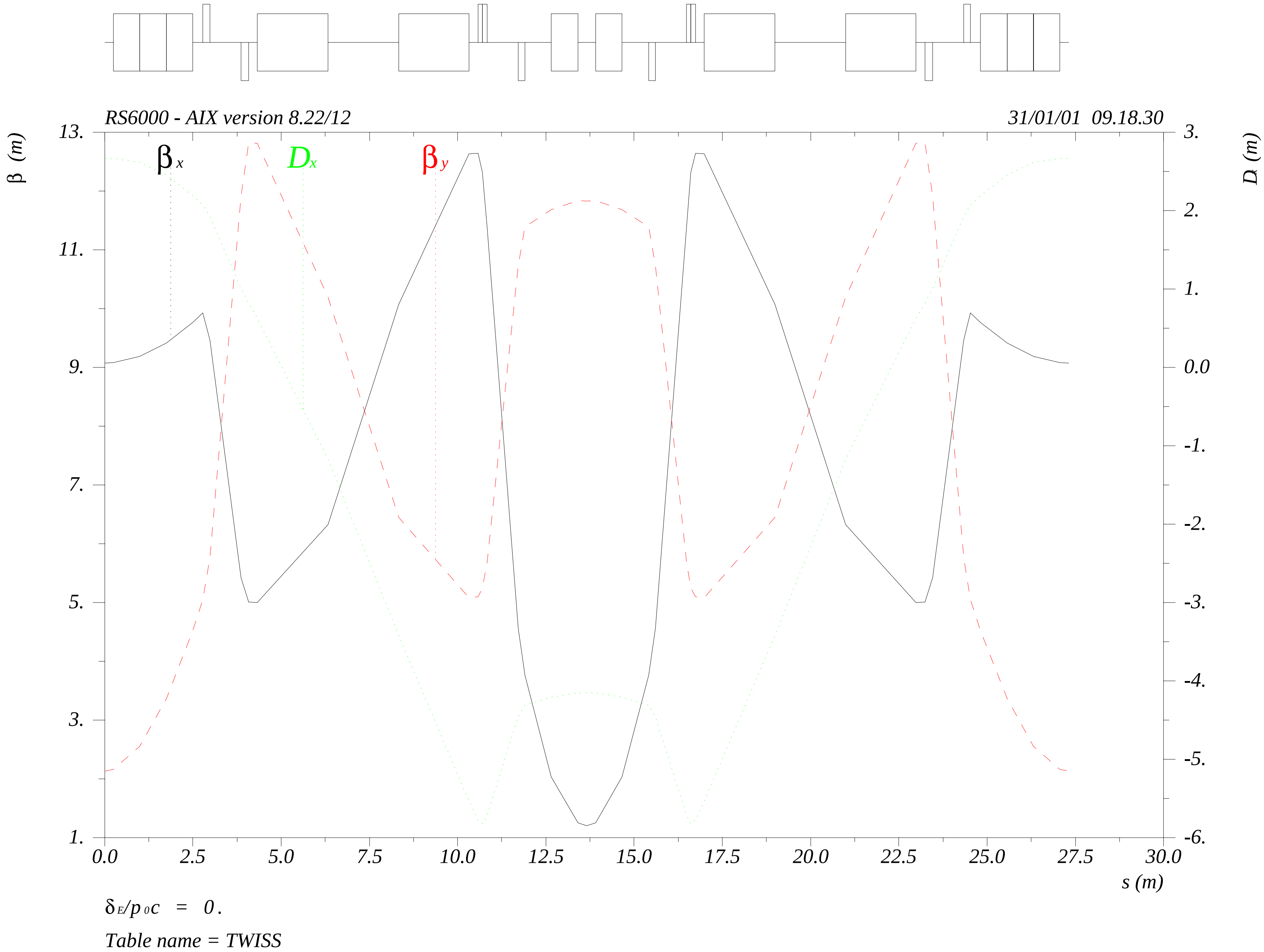
- Design specs
  - Output of Study I “preaccelerator” at 3 GeV
  - RLA to 20 GeV
- Design methodology
  - Semi-automated longitudinal design
  - Start with ellipse freom preaccelerator
  - Minimize energy spread
  - Barely fit into bucket
  - Phase rotate rapidly from incoming ellipse to “matched” ellipse
- Optimize cost as a function of number of linac passes
  - Costs based on FNAL study
    - Linac: 38 per GeV
    - Arc
      - Proportional to length (or, equivalently, degree-GeV)
      - Proportional to energy spread
      - 0.18 per half arc per GeV per percent
    - For comparison, RLA1 plus RLA2 in Study I were 500 units.

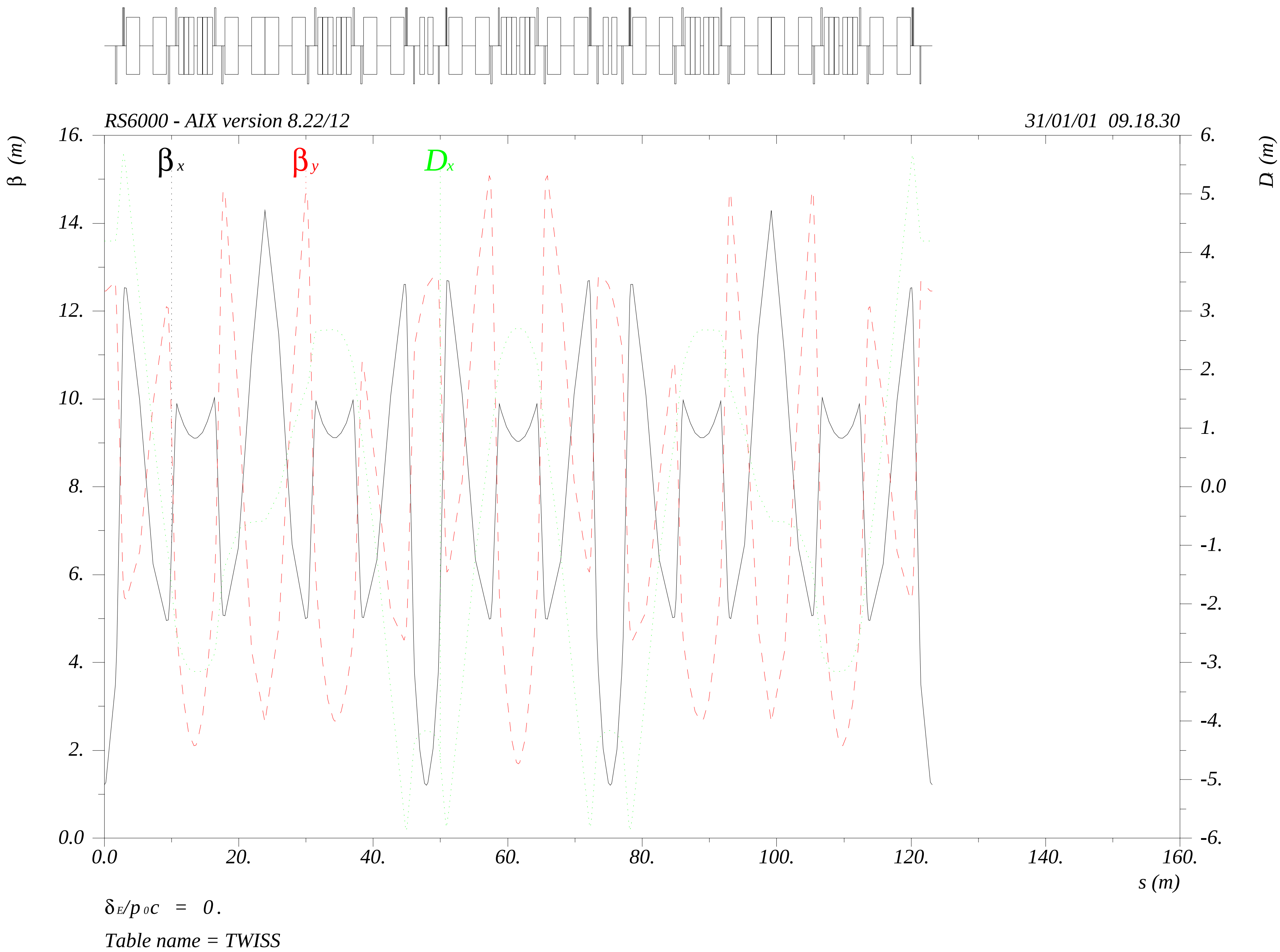
Results

- Optimum costs
  - Racetrack: 6 turns, 231 units
  - Dogbone: 7 linac passes, 205 units; 11% savings
  - Note: racetrack for 4 turns: 246 units; 7% premium
- Cost savings mostly in arcs
  - Dogbone: 16% more angle
  - Dogbone: slightly larger energy spreads
  - Dogbone: average length cut roughly in half due to short arcs
  - Motto: No savings if don't take shortcuts
- Cavaets
  - Storage ring cost: energy spread
    - Dogbone: ± 457 MeV
    - Racetrack: ± 322 MeV
  - Increased arc costs associated with reverse bend
  - Beamline crossings


Dogbone Total
Racetrack Total
Cost
400
350
300
250
200
150
100
50
0
0
5
10
Linac Passes


Dogbone Arcs
Dogbone Linac
Racetrack Arcs
Racetrack Linac
0
50
100
150
200
250
300
350
400
Cost
0
5
10
Linac Passes


RS6000 - AIX version 8.22/12
31/01/01 09.18.30
β (m)
D (m)
βx
Dx
βy
13.
11.
9.
7.
5.
3.
1.
3.
2.
1.
0.0
-1.
-2.
-3.
-4.
-5.
-6.
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
s (m)
δE/p0c = 0.
Table name = TWISS


RS6000 - AIX version 8.22/12
31/01/01 09.18.30
β (m)
D (m)
β_x
β_y
D_x
16.
14.
12.
10.
8.
6.
4.
2.
0.0
6.
5.
4.
3.
2.
1.
0.0
-1.
-2.
-3.
-4.
-5.
-6.
0.0
20.
40.
60.
80.
100.
120.
140.
160.
s (m)
$\delta_E/p_0c = 0.$
Table name = TWISS

FFAG Recirculators

- A couple of arc designs on the table
  - Smaller energy range: factor of 2-3
  - Isochronous and non-isochronous
- Problem is with longitudinal dynamics
- Getting phase right:
  - Prefer isochronous
  - Arc not perfectly isochronous
    - Limits number of turns before walk off crest
    - Shift phase of stored energy: mild frequency shift (few part 10^{-4})
  - No synchrotron osillations: beam loading gives energy drift
    - Two nearby frequencies: ride slope of beat wave
- Non-isochronous
  - Need significant phase shifting (frequency shift: couple 10^{-3} to couple 10^{-2})
- Proposed solution for frequency shift:
  - Store energy in SC storage cavities
  - Switch rapidly to NC accelerating cavities
    - Shift frequency of NC cavities until matches SC cavity, energy transfers
  - Ferrite in NC cavity to continue frequency shift
  - Less worry with energy loss in ferrite